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DEVELOP AN X-WINDOWS TOOL TO COMPUTE GAUSSIAN BEAM SYNTHETIC SEISMOGRAMS

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13. ABSTRACT *(Maximum 200 words)*

This report consists of two principal sections: an introduction in which the functional flow and the basic architecture of a prototype system for computing synthetic seismograms using the Gaussian Beam method are described, and a second section in which progress toward implementing that design is outlined. To maximize functionality, the design integrates as much as possible software already developed under the NMRD initiative: code for handling database transactions, inter-process communication and graphical display of seismograms are assumed to exist. The system has two modules. The first provides X-Windows graphics to allow the user to construct and manipulate two-dimensional earth models, and also to trace the propagation of seismic waves through those models. The second module computes synthetic seismograms and/or calculate traveltimes for models constructed with the first. It has no graphical component. The raytracing capabilities of the program have been found to be very fast, owing in part to the way the velocity model has been parameterized. Several figures demonstrating model construction and raytracing are included.

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1. OBJECTIVES

The principal objective of this project is to create an X-Windows-based graphics tool to compute rapidly and efficiently, synthetic seismograms for laterally heterogeneous, two-dimensional, isotropic velocity models using the Gaussian beam method. The existing Gaussian beam software is written in Fortran code and can be very labor intensive to use. Our goal is to construct an X-Windows Graphical User Interface (GUI) which will eliminate much of the tedium of introducing lateral heterogeneity into two-dimensional velocity models.

In this report, we describe the overall architecture of the modules and how they interface with software already developed under the rubric of the NMRD. A brief explanation of how Gaussian beam seismograms are computed is included for clarity. Finally we conclude with an outline of progress to date and our objectives for the remainder of the contract.

2. FUNCTIONAL OUTLINE

The functional flow for computing Gaussian beam seismograms and/or calculating traveltimes through heterogeneous media is shown in Figure 1. The first step is either to create an input model from scratch or to access a fully two-dimensional model which has been created previously. The former is generally done by beginning with a one-dimensional model and extending it into a second dimension. Once in this extended form the user may impose an overall heterogeneity, such as ellipticity in the case of a global model, or a localized heterogeneity, such as a sedimentary basin with low-velocity lens in the case of a regional model. Additional heterogeneity may be created by manually manipulating the model elements with a mouse. Whether created or read in and modified, the model may be stored at the end of this step.

The velocity model is specified as a series of knotpoints and triangles. Each knotpoint fixes v_p, v_s, and ρ at a point in space. Because the velocity gradient is assumed to be linear between each knotpoint, the velocity is effectively specified fully in two dimensions. (One exception is at discontinuities: there two knotpoints are spatially co-located and specify the velocity and density on each side of the discontinuity.) Knotpoints are grouped into triplets to form triangles. A value for Q_α and Q_β, the *P*- and *S*-wave attenuation, is assigned to the space enclosed by each triangle. The program tracks which triangles share knotpoints and are therefore "neighbors."

Under these linear gradient conditions, there is an analytical solution for the raypath across a triangle. Raytracing through the model is accomplished by stepwise tracing analytically through each component triangle along the raypath. Anelasticity is accounted for by computing a t^* operator using Q_α and Q_β from the triangles. This is the second step shown in Figure 1. Results from this step are also stored for later reference.

The essentials for traveltime calculation or seismogram computation are now complete. One should remember that in the Gaussian beam method, it is not necessary to compute rays which travel directly from source to receiver. Rather, it is sufficient to compute a number of rays which originate at the source and terminate within several

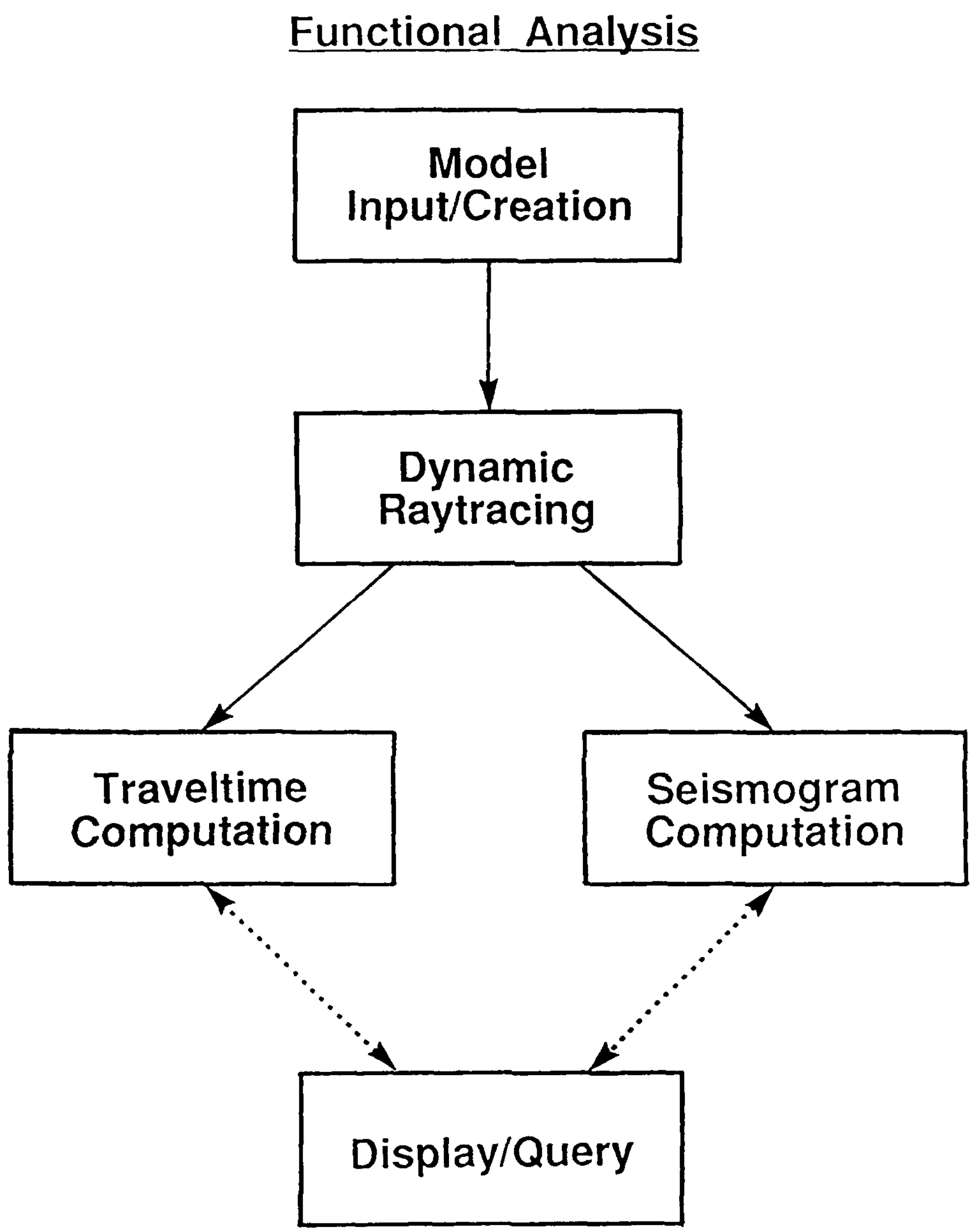

Figure 1.

wavelengths of the receiver. Therefore, to obtain a traveltime or seismogram, one must first specify the source-receiver geometry and phase, or component phases in the latter case.

System Architecture

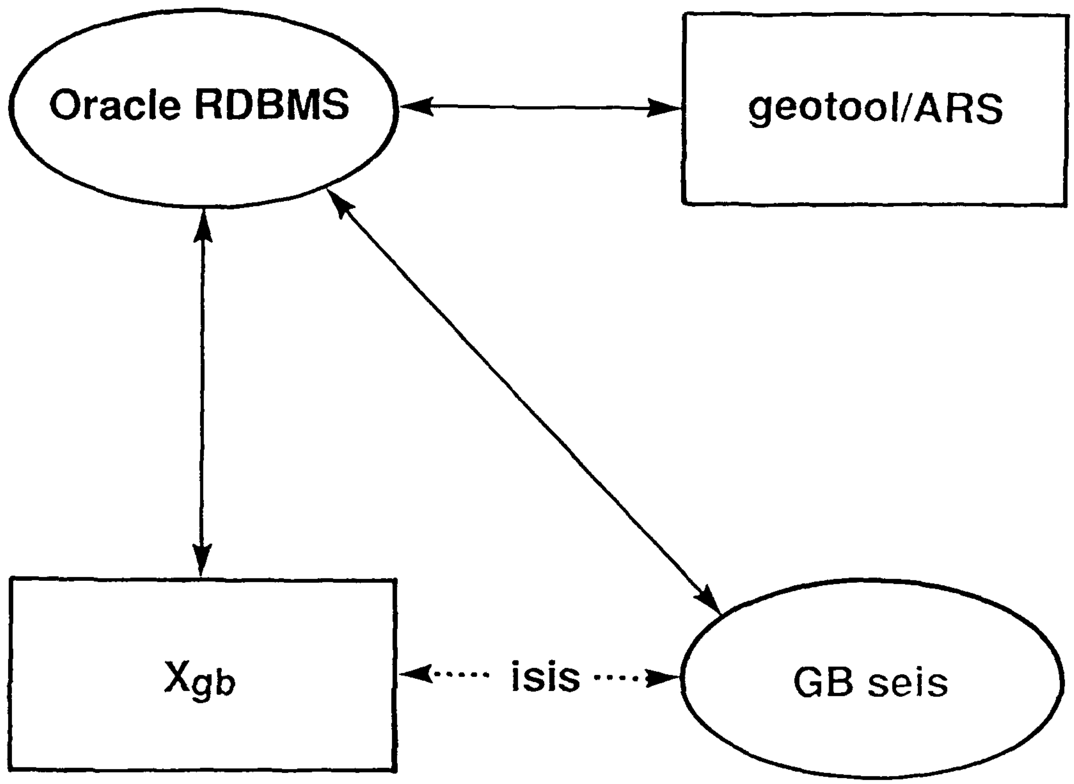

Figure 2.

This is represented by the display/query box at the bottom of Figure 1. Since the prerequisites have all been computed, one may repeatedly access the model and ray information to obtain traveltimes and seismograms for different receivers and focal mechanisms.

3. SYSTEM ARCHITECTURE

How the functional capabilities are realized is outlined in Figure 2. In this diagram, rectangles represent programs with an X-windows graphical component, ellipses enclose the names of background processes, and ISIS is the name of the interprocess communication (IPC) module employed by the NMRD system. The modules being developed for this project are *Xgb* and *GBseis*.

It is *Xgb* which is at the heart of this system. The X-windows interface allows the user to create or modify two-dimensional earth models. If a velocity structure is to be assembled from scratch, the user is presented with a suite of one-dimensional models,

either global, regional, or customized by the user. The one-dimensional model is recast into triangles extending laterally. Alternatively, the user may read in a model created with *Xgb* on a previous run. This is accessed from where it is stored on disc via the Oracle Relational Database Management System (RDBMS) running at the Center for Seismic Studies. A prototype application-specific database table to handle Gaussian beam model storage is shown in Table 1 as relation *gbmodel.*

Once the models are input, they may be modified in several ways. One way is to apply a spatial filter to all knotpoints. Examples of situations for which this may desirable are to account for ellipticity in global models, or for synclines or inclined layers in local or regional models. The outcome of the filtering process is displayed immediately, so the user can inspect to see if the results are satisfactory, and if not, can reverse the process.

Additionally, the user may introduce heterogeneity via the mouse by manipulating the spatial location of knotpoints or by selecting a triangle or series of triangles and allowing the user to modify the properties of those selected. This includes the velocities and densities assigned to the constituent knotpoints as well as the attenuation. The functionality is provided as an overlay of the filtering mechanism. That is to say, mouse manipulation may be done before or after a filtering operation.

Once the model is adjusted to the satisfaction of the operator, raytracing may be performed with *Xgb.* This is accomplished by specifying the initial ray parameter of the ray and by describing the discontinuity interactions, namely what discontinuities the ray encounters and whether it is reflected, transmitted, or converted there. The user has mouse control of the source location, and every time the source position is changed, rays are automatically retraced through the medium. The operator has the option of modifying the model and retracing the rays. Therefore iteration of model alteration, source position change, and ray specification can be done until the operator wishes to preserve the results. Like the model, raytracing results are stored in a file for later reference, and a pointer to this file location is passed to the Oracle RDBMS. A prototype table for storing this information is shown in Table 1 as relation *gbrays.*

The computational functions of *Xgb* are complete at this stage. Traveltime calculation and synthetic seismogram computation are performed by the non-graphic server process *GBseis.* This is accessed via IPC messages instructing it what function, traveltime or synthetic seismogram, to fulfill. If the function is traveltime calculation, *GBseis* will return its results via IPC reply. If it is seismogram computation, the results will be written to disk, registered in the database, and an IPC acknowledgment sent. *Xgb* will be able to form the proper IPC messages to prompt *GBseis* to perform the described calculations, and specifications of the IPC messages will be provided so that other processes will be able to do so as well.

By design, there is no capability in either *Xgb* or *GBseis* to display the resulting synthetic seismograms. In keeping with the NMRD goal of modular design and distributed processing, this task is left to modules such as the Analyst Review Station (ARS) or Geotool, both under NMRD development.

Relation:		gbmodel			
Description:		Gaussian beam models			
attribute name	field no.	storage type	external format	character positions	attribute description
modelid	1	i4	i8	1-8	model id
dir	2	c64	a64	10-73	directory
dfile	3	c32	a32	75-106	data file
commid	4	i4	i8	108-115	comment id
lddate	5	date	a17	117-133	load date

Relation:		gbrays			
Description:		Gaussian beam raytracing results			
attribute name	field no.	storage type	external format	character positions	attribute description
modelid	1	i4	i8	1-8	model id
dir	2	c64	a64	10-73	directory
dfile	3	c32	a32	75-106	data file
xsrc	4	f8	f16.3	108-123	x src coordinate
zsrc	5	f8	f16.3	125-140	z src coordinate
commid	6	i4	i8	142-149	comment id
lddate	7	date	a17	151-167	load date

Table 1.

4. PROGRESS

The basic core of the module *Xgb* is nearly complete. The code for model construction and kinematic raytracing has been translated from Fortran to C so that it may be more smoothly integrated into the X-windows display routines. The user may now select from a suite of one-dimensional models, the starting model that is projected into a second dimension and displayed using NMRD plotting widgets developed elsewhere.

Such a display is shown in Figure 3. Here a simple four-layer velocity model has been extended laterally. At this stage, all knotpoints at a given depth share the same velocity and density as befits the one-dimensional model from which they were generated. What cannot be shown in this black-and-white representation is that there are discontinuities between the first and second layers and between the second and third layers. On a color display, these discontinuities are shown in a different color to indicate they are different from normal triangle sides.

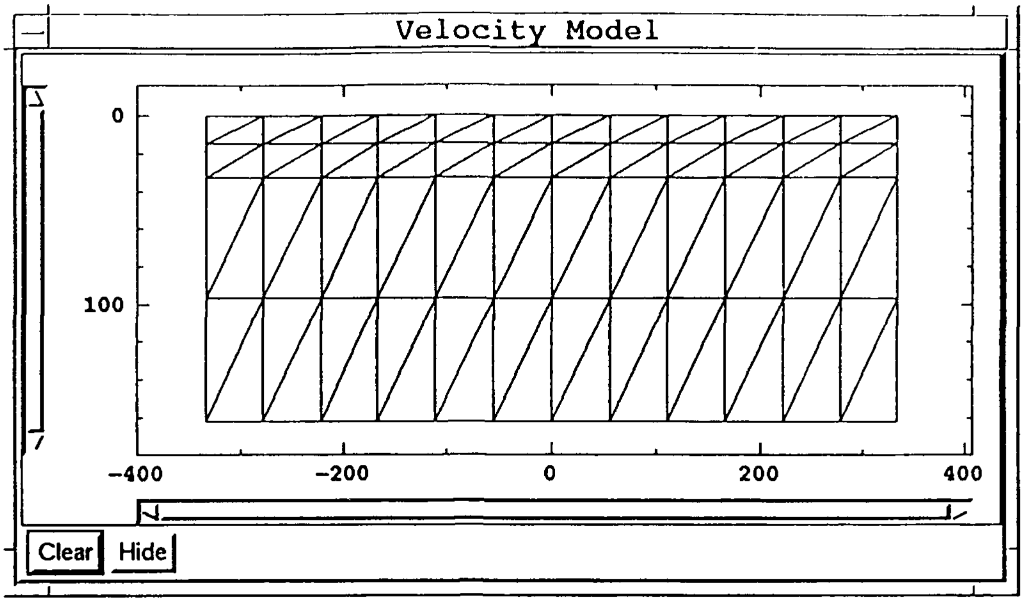

Figure 3

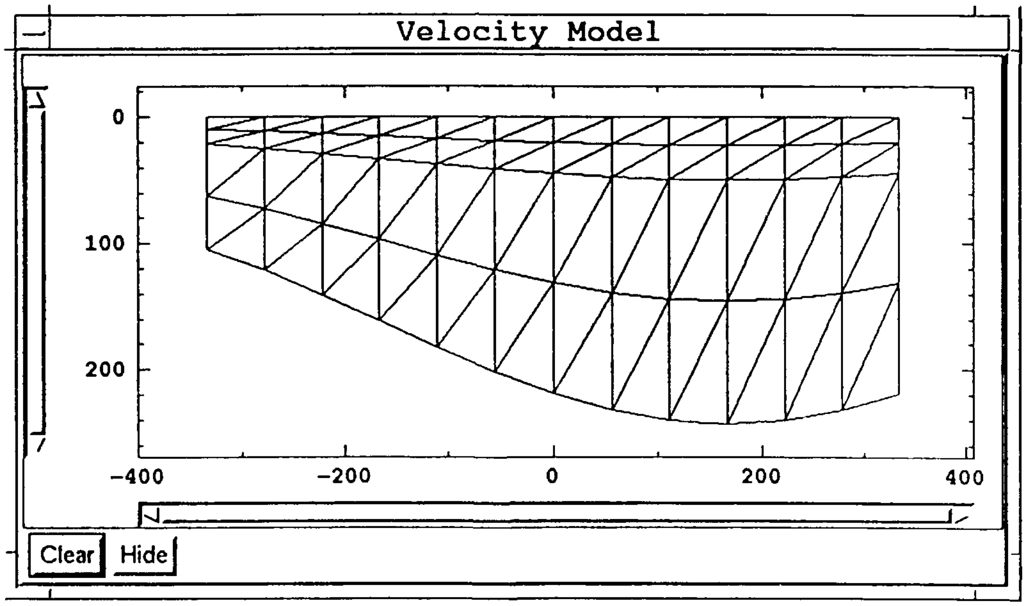

Figure 4

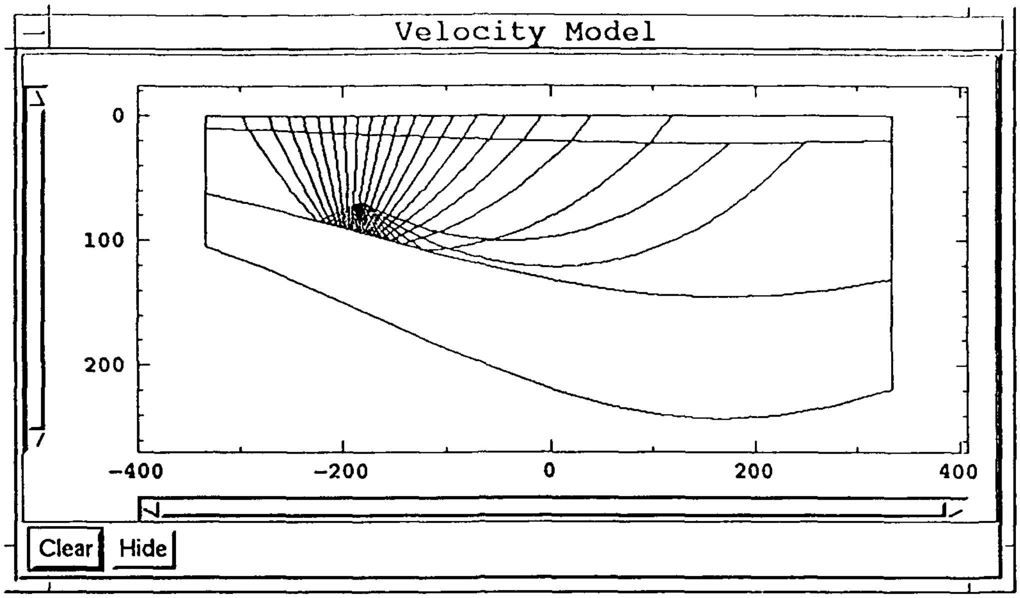

Figure 5

The capacity to warp the model into a simple synclinal or anticlinal form is now available. The results of applying this simple filter may be seen in Figure 4. Here the one-dimensional model of Figure 3 has been filtered to deform it into a broad synclinal structure. The properties of the knotpoints have not been changed -- only their vertical coordinates. As stated above, this is just one of several filters the operator will be able to apply in the completed version.

The code for accomplishing kinematic raytracing is complete. Figure 5 shows rays reflecting off a discontinuity of the model shown in Figure 4. The triangles are omitted from the display here for clarity -- only the rays and the discontinuities are shown. Before synthetic seismograms can be computed, the dynamic aspects of the raytracing must be incorporated. This is a straightforward extension of the raytracing functions already coded.

5. FUTURE PLANS

There are three principle developments which must be accomplished in the near term for this system to function: (1) the dynamic raytracing must be coded into *Xgb*, (2) the code for the *GBseis* module must be translated from Fortran to C and IPC hooks installed, and (3) the *Xgb* interface must be modified to allow the user to manipulate individual knots and triangles. At this writing, the logic for (3) had been conceived, and we anticipate only two or three man-days for it to be completed. Likewise, (1) involves another Fortran translation, but with the C structures already implemented, this should not require more than 1-2 man-weeks. The greatest task may be (2), but we expect that the structure of C is so much better suited for computations of this kind that a substantial amount of resources will not be required to complete that task.

When these problems are solved, refinements to the *Xgb* will be added to make the module easier to use. Included in this are plans to (1) allow phases whose rays are to be computed to be selected from a menu list, (2) specify source type as either explosion or double couple, and if the latter, allow the user, via graphics, to alter the orientation of the fault planes and have the changes be reflected in the computed seismograms, and (3) allow the user to project "target" receivers onto the model and check the ray density of rays terminating within a fixed number of wavelengths of the target.

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DTIC	INFO CTR	2
GL/LWH	CIPAR	1
GL/LWH	LEWKOWICZ	1
GL/XO	XO	1
LLNL	HANNON	2
OSD	DORE	1
SANDIA	CHAEL	1
USGS	LEITH	1
USGS	MASSE	1
WL/NTESG	REINKE	1
TOTAL NUMBER OF REPORTS		88